

## A PROJECTILE OR WAR-HEAD

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### BACKGROUND OF THE INVENTION

The invention relates to projectiles or war-heads to fight targets, in particular armoured targets, with an inner arrangement for the dynamic formation of bulging zones and for achieving large lateral effects.

In a plurality of fields of application for projectiles and war-heads it is also desirable, in addition to the demanded penetrating power, to achieve the highest possible effect over area (lateral effect) for increasing the efficiency. This is required in particular in the case of projectiles against flying targets such as fixed wing aircraft, unarmoured helicopters or other aircraft, which from a terminal ballistic viewpoint belong to the easier target classes.

In this field, however, so-called "hardened" objects appear increasingly, so that in addition to the high lateral effects partially also high penetrating powers are demanded. The same applies in a comparable way to other structures such as ships, for example. But also in respect of armour-piercing projectiles of high penetrating power, which must be achieved with increasingly slenderer and longer penetrators, securing a sufficient lateral effect during the target penetration or in the target interior is of increasing importance. These requirements apply both to cannon launched kinetic energy projectiles (kinetic energy projectiles) and to war-heads with kinetic energy effective bodies or so-called hybrid projectiles made from kinetic energy effective bodies and hollow charges.

Pursuant to German Pat. No. DE 25 54 600 C1 a solution is proposed, by means of which an improvement of the lateral effect of kinetic energy projectiles is achieved in

1 such a way that by way of a forward core, which conically tapers in its rear end, the  
2 said conical end is delayed on impact and the subsequent penetration process and is  
3 pushed in between the prefabricated subprojectiles which are located in the rear,  
4 multipart core and accelerates the same radially either immediately or by way of a  
5 deformable transition piece. The function of this constructively sophisticated solution  
6 was proved both in spin-stabilized and aerodynamically stabilized projectiles (dart  
7 projectiles). However, the efficiency is particularly limited owing to the constructional  
8 requirements. Particularly where thin target structures are concerned they are not  
9 effective. Such solutions are very complex and thus cost intensive. All these factors  
10 strongly limit the application.

11  
12 For the purpose of achieving increased lateral effects tests have been made with  
13 projectiles which on impact on a target either fall apart or scatter. These concern  
14 effective bodies with brittle steels or hard metals or brittle heavy metals, for example.  
15 Such approaches to solutions do not lead to very large splinter conical angles in  
16 comparison with the usual penetrators. The possibilities concerning construction and  
17 materials are strongly limited in this case too. Moreover, such solutions are preferably  
18 suitable for spin-stabilized projectiles only. Moreover, the penetrating power of such  
19 projectiles decreases drastically, so that they are only useful for a limited spectrum of  
20 applications. Such solutions are particularly less efficient in the case of thinner  
21 targets, which also applies to structured targets (multi-plate targets).

22  
23 In European Pat. No. EP 0 343 389 A1 the projectile core of a discarding sabot  
24 projectile is described which consists of a relatively brittle central portion of the  
25 projectile core in which a relatively ductile projectile core pin is inserted which is  
26 anchored at its rear end in the rear part of the projectile core and at its front end in a  
27 tip of the projectile core. For the brittle middle portion of the projectile core frangible  
28 tungsten is preferably proposed, whereas the projectile core pin consists of a ductile  
29 tungsten, hard metal or any other terminal-ballistically effective material. The  
30 relatively brittle middle portion of the projectile core already disintegrates during the

1 penetration of the first target plate of a multi-layer armour-plating, whereas the ductile  
2 projectile core pin does not fragment during the penetration process, but instead  
3 successively penetrates the following target plates and thus degrades continuously in  
4 its length and mass. The relatively thin and thus low-mass projectile element is  
5 particularly not suitable for achieving a larger depth effect or for penetrating deeper  
6 targets with a continuous lateral effect. The densities of the brittle middle portion of  
7 the projectile core and the ductile projectile core pin are nearly the same. A high  
8 lateral effect of the splinters in combination with a penetration of multi-layer target  
9 plates is thus not given.

10  
11 WO 92/15836 A1 discloses a spin-stabilized armour-piercing splinter-producing  
12 projectile which is formed from a projectile case with a material of high density and a  
13 forward head element of the same material in which the disintegration of the projectile  
14 case occurs mechanically with the help of a pretensioned heavy material which is  
15 located in a pocket hole in the rear part of the projectile casing and a groove in the  
16 case structure. Tungsten powder is proposed as compressed filling material. This  
17 solution is as ineffective in thin targets as in deep targets. It is also impossible to  
18 achieve a terminal-ballistically effective compression in a constructional manner  
19 owing to the powdery filling material.

20  
21 European Pat. No. EP 0 238 818 A1 describes a spin-stabilized discarding sabot  
22 projectile which consists of a hollow fragment casing which is closed at the back and  
23 front and a projectile tip attached thereto. An inert powder with a density of not less  
24 than 10 g/cm<sup>3</sup> is proposed. The fragment casing is provided with predetermined  
25 breaking points which determine the size of the individual splinters. The fragment  
26 casing is to fragment after the penetration of the projectile and break down into  
27 individual effective splinters. The powdery filling made from tungsten is ejected after  
28 the penetration owing to the rotation of the projectile. A high lateral and,  
29 simultaneously, high-depth effect cannot be achieved with such a concept, as the  
30 invention is based primarily on the centrifugal forces of a spin projectile and despite

1 prefragmentation the tungsten powder will not sufficiently break down the  
2 encompassing thick jacket in the radial direction owing to the natural hollow spaces.  
3 Moreover, the powder filling is intended as a replacement for the bursting and burning  
4 charge, with the high density being intended to directly produce terminal ballistic  
5 effects.

6  
7 A further fragmentation principle for achieving a lateral effect is proposed in the  
8 specification (JP 08061898) in which a reactive metal is arranged in a metal cylinder  
9 which reacts chemically thermally with air and water when the armour-piercing  
10 ammunition collides with an object. It is obviously intended in this case to produce a  
11 "quasi" explosion and burning effect by the special reaction of the metal so as to  
12 achieve a strong radial destructive force.

13  
14 A non-armour-piercing method to achieve an increased lateral effect with a projectile  
15 after the impact on or penetration of a target is known from German Pat. No.  
16 DE 28 39 372 A1, in which a projectile is proposed for hunting purposes which  
17 consists of a massive projectile casing which is provided with a central pocket hole  
18 extending from the front to the rear in which a filling, preferably made from lead, with  
19 cavities is introduced. In this design the heavier material is located in the interior of  
20 the ambient casing and causes a mushrooming of the forward projectile part during  
21 the penetration of the soft target body. In this way the projectile is enabled to transmit  
22 its energy to the body of the hunted game in an intended manner and achieve a  
23 higher spreading effect. A lateral fragmentation of the projectile body or a lateral  
24 splintering effect is not intended, yet it is even undesirable. A similar effect is achieved  
25 with the prohibited dum-dum principle against persons.

26  
27 With respect to solutions provided for armour-piercing projectiles with high penetration  
28 power which must be achieved with increasingly slenderer and longer penetrators,  
29 few inventions are known whose subject matter is the achievement of a sufficient  
30 lateral effect. Usually, the objective of such projectile designs is solely the

1 achievement of a large depth power.

2  
3 German Pat. No. DE 40 07 196 A1 describes a hypersonic kinetic energy projectile  
4 with a carrying outer casing which encloses a mass body of heavy bulk material,  
5 preferably tungsten and depleted uranium powder. In this invention the casing is  
6 merely used for the stability of the insert consisting of the heavy metal powder during  
7 the launch acceleration and the flying phase. The projectile, which is impacted on the  
8 target at a very high speed, achieves its high depth effect because in the hyper speed  
9 range the strength of the material of the penetrator no longer or only hardly influences  
10 the penetration power. At lower speeds the depth power thus decreases strongly. The  
11 lateral effect is marginally low. These projectiles are known as so-called segmented  
12 penetrators.

13  
14 In US Pat. No. 5,440,995 a heavy metal penetrator is presented which is composed of  
15 tungsten whiskers. In the case of common penetrators made from polycrystalline  
16 tungsten heavy metal, a plastic or hydrodynamic head (mushroom) forms during the  
17 penetration of an armoured target, which head influences or reduces the penetrating  
18 depth power. The proposed penetrator concept is to prevent this formation of head  
19 and thus to increase the depth power. The principle is therefore solely aimed at the  
20 achievement of the highest possible depth power. A lateral effect is not given.

21  
22 A subcaliber kinetic energy projectile with a high length/ diameter ratio and a hybrid  
23 arrangement is disclosed in European Pat. No. EP 0 111 712 A1 which substantially  
24 consists of a main, intermediate and tip body. The intermediate body, consisting of a  
25 brittle sintered material of high density such as tungsten or depleted uranium, is  
26 connected in a plane abutting joint area on the rear side with the main body and on  
27 the front side with the tip body also in a plane abutting joint area, with both the main  
28 body and the tip body being formed from a tenacious sintered material of high density  
29 such as the aforementioned metallic materials. On impact on an armoured target the  
30 particles formed from the brittle material of the intermediate body are to widen the

1 penetration crater and cause a strong blasting effect after the first target plate. Such  
2 free buffer layers principally act both in a pressure- and performance-reducing way.  
3 The splintering effect remains limited both locally as well as laterally owing to the  
4 design and the low differences in density between the brittle and tenacious sintered  
5 materials, as the brittle intermediate body is compressed on impact in the axial  
6 direction by the tip and main body and, together with these two ballistically highly  
7 effective masses, is driven purely axially through the penetration crater.

8  
9 A further development of the invention as discussed above according to European Pat.  
10 No. EP 0 111 712 A1 is described in German Pat. No. DE 33 39 078 A1 in which the  
11 connection between the brittle intermediate body of high density and the ductile main  
12 body of also high density, or same density, or even the brittle intermediate body per  
13 se is stabilized by a high-strength thin casing. Although this causes an improvement  
14 of the stability of the kinetic energy projectile during the launching or flying phase, it  
15 does not change ,however, anything with respect to the terminal ballistic effect as  
16 compared with the invention pursuant European Pat. No. EP 0 111 712 A1.

17  
18 From the state of the art as discussed above one can derive that to date practically no  
19 solutions, and particularly no simple ones, are known for an armour-piercing projectile  
20 where a high lateral effect is achieved in different targets in conjunction with an  
21 adequate depth effect.

22  
23 It is further known that by using glass bodies which are enclosed under high pressure  
24 during impact and penetration of projectiles it is possible to achieve increased lateral  
25 effects. These effects are caused by the special dynamic behaviour of glass which  
26 has been used for decades in the area of the protection of armour against hollow  
27 charges. Accordingly, the use of glass by way of a so-called "crater breakdown" leads  
28 to an influence on the stream during the penetration and thus to a considerable  
29 reduction of the penetration depth.

1 Any application of brittle materials such as glass or ceramics as dynamically acting  
2 medium is naturally subject to considerable limitations concerning the production  
3 techniques for the projectiles and, optionally, warheads and concerning the  
4 transmission of forces such as during the acceleration phase of the projectiles and  
5 warheads, for example. The technical problems in the introduction of glass into the  
6 respective hollow spaces of a projectile body are an example. In prefabricated glass  
7 bodies the constructional possibilities for use are strongly limited. Moreover, the  
8 arrangement of the contact surfaces with the ambient (enveloping) bodies requires  
9 considerable technical efforts. Moreover, glass and ceramics are limited to a certain  
10 density range.

11  
12 In the case of the introduction of glass by way of casting, which means that ceramic  
13 materials can principally be omitted owing to the required extremely high sintering  
14 temperatures, tensions in the glass body per se would have to be expected by the  
15 cooling process even if a perfect casting could be achieved. These tensions may in  
16 some cases also have a negative effect on the ambient bodies. Moreover, as was  
17 already mentioned above, contact problems would arise on the transition surfaces  
18 between the medium and the parts enclosing this medium. But even during the  
19 melting of glass temperatures occur which in many cases would lead to impermissible  
20 changes in the ambient materials. Moreover, in the use of these fragile and impact-  
21 sensitive materials as a dynamically active medium it is not necessary, with the  
22 principal exception of pure pressure forces (primarily in the sense of a polydirectional  
23 or hydrostatic pressure), to transmit any technical stresses, and thus forces (tension  
24 and shearing forces), worth mentioning.

25  
26 Moreover, in the Germano-French Institute (hereinafter referred to as "ISL")  
27 experiments with provided glass fibre reinforced plastic materials were performed. It  
28 was intended to test primarily whether glass could be replaced as the bearer of the  
29 effect and whether in the case of a positive answer to this question it could be  
30 assumed, analogously to the protected technology, that the glass content (resin

1 content) or the hardness of the glass fibre reinforced plastic material, for example, are  
2 relevant for the operativeness and that consequently with specially highly filled  
3 assortments it is possible to achieve a fragmentation factor comparable to pure glass.  
4 It is was also proposed to principally verify the previously presumed "glass effect" by  
5 changing the resin content.

6  
7 The experiments confirmed that with glass fibre reinforced materials with a high share  
8 of glass (a share of approx. 80 % by weight) terminal ballistic effects can be achieved  
9 which correspond to those of pure glass as working medium. These first experiments  
10 led to the result, however, that with materials which comprise a considerably lower  
11 share of glass it is possible to achieve in a surprising manner respective or even  
12 considerably higher lateral effects. The thus resulting further considerations and the  
13 experiments thus additionally proposed to the ISL and performed there led to the  
14 finding that the effects originally described in connection with glass are obviously not  
15 so relevant for the increased lateral effects observed in this connection.

16  
17 According to the latest findings it is important to introduce into a body with terminal  
18 ballistic effect or into a casing made from a material which has a terminal ballistic  
19 effect a "bulging medium" (hereinafter referred to as AWM) which shows little  
20 compressibility and comprises a comparably low density or terminal ballistic power in  
21 comparison with the actual effective bodies. The same naturally also applies in the  
22 case that the AWM is located between an outer body with terminal ballistic efficiency  
23 and a central penetrator.

24  
25 The terminal ballistic power of an effective body is determined in the range of lower  
26 impact speeds (below 1000 m/s) by its mechanical properties and its density, and in  
27 the upper speed range (more than 1000 m/s) increasingly by its density.

28  
29 In the doctoral thesis "Das Verhalten von Kupferstiften beim Auftreffen auf  
30 verschiedene Werkstoffe mit Geschwindigkeiten zwischen 50 m/s und 1650 m/s (The



behaviour of copper pins on impact on various materials at speeds between 50 m/s and 1650 m/s)" by Dipl.-Ing. Günter Weihrauch of February 12, 1971 of the University (TH) Karlsruhe and in the ISL report with the same name a number of things are said about this behaviour on pages 98 to 101. The following pressure balance arises in a co-ordinate system which is moved along with the stagnation point:

$$\frac{1}{2} \rho_P * (v - u)^2 = \frac{1}{2} \rho_Z * u^2 + F$$

with  $v$  = projectile speed,  $u$  = penetration speed,  $\rho_P$  = density of the projectile material,  $\rho_Z$  = density of target material,  $F$  = factor which is changeable with the bulging speed of the bulging zone and depends both on the dynamic tenacity of the target and of the projectile material and thus also of the AWM.

Accordingly, the influences arising from the compressibility of the material and the dissemination speeds of the elastic and plastic faults are also included by way of term  $F$ . At higher speeds  $v$  of the projectile the share of  $F$  decreases and the known Bernoulli's equation applies with sufficient accuracy:

$$\frac{1}{2} \rho_P * (v - u)^2 = \frac{1}{2} \rho_Z * u^2$$

From this equation one receives for the penetration speed  $u$ , which also known as crater base speed, a term where the speed  $u$  only depends on the projectile speed  $v$  and the material densities  $\rho_Z$  and  $\rho_P$ :

$$u = v / (1 + \sqrt{(\rho_Z / \rho_P)}).$$

If the projectile does not consist of a uniform material, this term applies under the prerequisite of high projectile speed  $v$  for every single material in the projectile, with the respective material density such as  $\rho_{AWM}$  or  $\rho_{Casing}$  having to be inserted for  $\rho_P$ .

1 It can easily be derived therefrom that materials with lower density than the actual  
2 penetrator material with high terminal ballistic power will achieve lower penetration  
3 speeds at high projectile speeds and thus will remain behind in the target as  
4 compared with the ballistically highly effective penetration material...

5  
6 At relatively low projectile speeds  $F$  becomes a speed term on an equal standing, i.e.  
7 the dynamic strengths of the materials involved are co-decisive. For the achievement  
8 of rapidly commencing and high lateral effects, materials with low strength should be  
9 used as bulging medium. Concerning the density one still has a relatively large  
10 amount of leeway.

11  
12 Accordingly, at high projectile speeds (more than 1000 m/s) one can vary the density  
13 of the AWM, because then the mechanical properties do not play any major role any  
14 more.

15  
16 At very high speeds (1500 m/s up to several km/s) one can usually entirely neglect  
17 the dimensional stability of projectile and target material, so that the strength of the  
18 materials involved does not play any role any more. In this case metallic and other  
19 materials can be treated approximately as liquids.

20  
21 The speed from which the strength of the matter can be ignored depends, however,  
22 strongly on the respective properties of the material. Accordingly, these impact  
23 phenomena from the high-speed range already occur at relatively low speeds when  
24 dense and simultaneously dynamically soft materials such as lead, copper or  
25 tantalum are involved.

26  
27 These considerations show that the effectiveness of the arrangements as proposed  
28 here is not limited to a specific speed range, but is present both from relatively low  
29 impact speeds (some 100 m/s), as occur at large fighting distances for example, right  
30 up to very high impact speeds in the magnitude of several km/s, as occur for example

1 in impact situations with so-called tactical missiles (TBM defence).  
2

3 In line with the above considerations it is necessary to influence the dynamics of the  
4 inner bulging zone in projectiles and war-heads over wide limits and with very simple  
5 means.  
6

## 7 SUMMARY OF THE INVENTION 8

9 It is therefore an object of the present invention to arrange projectiles and war-heads  
10 with simple means in such a way that the same can both achieve a strong lateral  
11 effect and simultaneously ensure high penetration depths if required.  
12

13 This object, and others which will become apparent hereinafter, is attained in  
14 accordance with the present invention by radially encompassing a bulging medium in  
15 the form of a material which is substantially terminal-ballistically ineffective by an  
16 outer body in the form of a penetration material which is considerably more  
17 terminal-ballistically effective.  
18

19 Further features, details and advantages arise from the description below in  
20 conjunction with the claims and the individual figures.  
21

## 22 BRIEF DESCRIPTION OF THE DRAWING 23

24 The above and other objects, features and advantages of the present invention will  
25 now be described in more detail with reference to the accompanying drawing in  
26 which:  
27

28 Figs. 1A – 1C show in three different phases a principal representation of  
29 the penetration and bulging process in accordance with the invention;

1 Figs. 2A – 2C show in three different phases a principal representation of  
2 the penetration and bulging process in accordance with the invention with an  
3 additional central penetrator;

4  
5 Figs. 3A – 3C show in three different phases a principal representation of  
6 the penetration process and the lateral production of splinters;

7  
8 Figs. 4A – 4B show a principal representation of the process in  
9 accordance with the invention for a two-plate target;

10  
11 Fig. 5 shows a principal representation of the process in accordance with the  
12 invention for an arrangement with a central penetrator and the full penetration through  
13 a two-plate target;

14  
15 Fig. 6 shows a principal representation of the experimental model projectile;

16  
17 Fig. 7 shows an X-ray flash photograph of an experiment with glass fibre  
18 reinforced plastic material as a bulging medium (AWM);

19  
20 Fig. 8 shows an X-ray flash photograph of an experiment with a hollow model  
21 projectile without bulging medium;

22  
23 Fig. 9 shows an X-ray flash photograph of a further experiment with a glass  
24 fibre reinforced plastic material as a bulging medium;

25  
26 Fig. 10 shows an X-ray flash photograph of a further experiment with  
27 aluminium as a bulging medium;

28  
29 Fig. 11 shows an X-ray flash photograph of a further experiment with a  
30 bulging medium of particularly low density (PE);

1        Fig. 12        shows the crater, represented on a grid, of the reference  
2 experiment (Fig. 8) with a hollow penetrator without bulging medium;

3  
4        Fig. 13        shows the splinter picture, represented on a grid, of the  
5 experiment with glass fibre reinforced plastic material pursuant to Fig. 9 as a bulging  
6 medium;

7  
8        Fig. 14        shows the splinter picture, represented on a grid, of the  
9 experiment with aluminium pursuant to Fig. 10 as a bulging medium;

10  
11       Fig. 15        shows the splinter picture, represented on a grid, of the  
12 experiment with PE pursuant to Fig. 11 as a bulging medium;

13  
14       Fig. 16        shows an X-ray flash photograph of a further experiment with  
15 glass fibre reinforced plastic material as a bulging medium and a thinner first target  
16 plate;

17  
18       Fig. 17        shows an X-ray flash photograph of a further experiment with  
19 glass fibre reinforced plastic material as a bulging medium pursuant to Fig. 9 and a  
20 low impact speed ( $< 1000 \text{ m/s}$ );

21  
22       Fig. 17A       shows the splinter picture, represented on a grid, of the  
23 experiment pursuant to Fig. 17;

24  
25       Fig. 18        shows a principal constructional proposal on the introduction of a  
26 prefabricated bulging medium body and fixing by a thread and gluing/soldering;

27  
28       Fig. 19        shows a principal constructional proposal on the introduction of a  
29 prefabricated bulging medium body and fixing by a connecting medium;

1           Fig. 20       shows a principal constructional proposal on the introduction and  
2   fixing of a prefabricated bulging medium body with random surface roughnesses;

3  
4           Fig. 21       shows a modified constructional proposal according to Fig. 20  
5   concerning the introduction and fixing of a prefabricated bulging medium body;

6  
7           Fig. 22       shows a sectional view through a projectile with a bulging medium  
8   and a central penetrator pursuant to Fig. 2;

9  
10          Fig. 23       shows a sectional view through a projectile with a bulging medium  
11   and a central penetrator and additional bridges as subprojectiles;

12  
13          Fig. 24       shows a sectional view through a projectile with a bulging medium  
14   and a central penetrator and additional rod-shaped or successively disposed terminal-  
15   ballistically effective bodies;

16  
17          Fig. 24A      shows a sectional view through a projectile with a bulging medium  
18   without a central penetrator and additional rod-shaped or successively disposed  
19   terminal-ballistically effective bodies;

20  
21          Fig. 25       shows a sectional view through a projectile with a bulging medium  
22   and a central penetrator and additional notches on the inner side of the terminal-  
23   ballistically effective outer body;

24  
25          Fig. 26       shows a sectional view through a projectile with a bulging medium  
26   without a central penetrator and additional notches on the outer side of the terminal-  
27   ballistically effective outer body;

28  
29          Fig. 27       shows a sectional view through a projectile with a bulging medium  
30   and a central penetrator and any other additional bodies embedded in the bulging

1 medium and being effective in a terminal ballistic or any other manner;

2  
3 Fig. 28 shows a sectional view through a projectile with a bulging medium  
4 without central penetrator and any other additional bodies embedded in the bulging  
5 medium and being effective in a terminal ballistic or any other manner;

6  
7 Fig. 29 shows a sectional view through a projectile with a bulging medium  
8 and four centrally arranged penetrators;

9  
10 Fig. 30 shows a sectional view through a projectile with a bulging medium  
11 and a centrally arranged penetrator with a square (random) cross section;

12  
13 Fig. 30A shows a sectional view through a projectile with a bulging medium  
14 and a centrally arranged cylindrical penetrator with a hollow chamber ;

15  
16 Fig. 31 shows a partial sectional view through a projectile with a  
17 graduated arrangement of the bulging medium;

18  
19 Fig. 32 shows a partial sectional view through a projectile with a partial  
20 arrangement of the bulging medium for the achievement of a high initial penetration  
21 power;

22  
23 Fig. 33 shows a further partial sectional view through a projectile with  
24 three dynamic zones for the achievement of different lateral and depth effects;

25  
26 Fig. 34 shows a sectional view through a projectile with a central  
27 penetrator and two radially arranged dynamic zones for the achievement of different  
28 lateral and depth effects;

29  
30 Fig. 35A shows a sectional view through a projectile with a bulging medium

1 without a central penetrator and an outer casing made from a ring of longitudinal  
2 structures;

3  
4 Fig. 35B shows a sectional view through a projectile with a bulging medium  
5 without a central penetrator and two different outer casings;

6  
7 Fig. 35C shows a sectional view through a projectile with a bulging medium  
8 without a central penetrator and an outer casing in which random bodies are  
9 embedded;

10  
11 Fig. 35D shows a sectional view through a projectile with a bulging medium  
12 without a central penetrator and a ring of subpenetrators on the inner side of the outer  
13 casing;

14  
15 Fig. 36 shows a projectile with a bulging medium and a hollow tip;

16  
17 Fig. 37 shows a projectile with a bulging medium and a tip filled with a  
18 bulging medium;

19  
20 Fig. 38 shows a projectile with a bulging medium and a massive tip;

21  
22 Fig. 39A shows a special shape of the tip in which the bulging medium  
23 reaches into the tip;

24  
25 Fig. 39B shows a special shape of the tip which in partial zones contains  
26 the bulging medium.

## 27 28 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

29  
30 The sequence of the penetration and bulging process in accordance with the



1 invention is shown in a principal and schematic manner in Fig. 1.

2  
3 Owing to its specific properties, the inner and enclosed bulging medium (AWM) 1  
4 remains behind relative to the ambient terminal ballistic effective body 2 during the  
5 piercing and penetration. Owing to its compressibility, which is also limited under the  
6 high occurring pressures, a lateral flattening and thus a dynamic bulging of the  
7 ambient material 2 occurs through the material of the bulging material 1 which  
8 continues to flow from behind.

9  
10 This process is determined by the physical and mechanical properties of the involved  
11 materials 1 and 2. The dynamic bulging usually leads to a tearing open or  
12 fragmentation of the outer body (casing) 2. In conjunction with its mechanical  
13 properties, dimensions, its density and speed (pass-by speed), an angular range  
14 arises in which the arising partial penetrators or splinters move.

15  
16 Fig. 1 shows the three penetration statuses 1A, 1B and 1C, with 1A showing a first  
17 phase, 1B a second phase and 1C a third phase of the process. In the section 1A the  
18 projectile consisting of a bulging medium 1 and a terminal-ballistically effective  
19 casing 2 is currently impacting on the target plate 3. In the representation 1B a  
20 pressure zone 4 has built up through the reduced penetration of the bulging medium 1  
21 into the target material 3. This leads to a bulging and deflection zone 5 of the casing  
22 which is passing by. This process has continued further in representation 1C. The  
23 pressure and bulging zone 4a has widened and remains behind the passing casing in  
24 an increasingly stronger way. The deflected or bulging zone 5a increases in a  
25 respective manner.

26  
27 Fig. 2 shows the process pursuant to Fig. 1 with a projectile in which a central  
28 penetrator 6 is additionally provided. Here too three different penetration  
29 statuses 2A, 2B and 2C are shown with respect to different penetration times. At the  
30 time 2B the pressure and bulging zone 4 has formed between the passing casing 2,

1 which is bulged or deflected in the deformation zone 5, and the central penetrator 6  
2 which also penetrates more rapidly and usually comprises at higher impact speeds a  
3 plastic or hydrodynamic head 6a. Section 2C shows this process in an even later  
4 status. The pressure and bulging zone 4a is enlarged and the casing 2 is further  
5 deformed via the deflection zone 5a. Owing to its new direction of movement, the  
6 deflected zone 5b penetrates the target plate 3 with a considerably increased radial  
7 component.

8  
9 Fig. 3 describes in section 3A,3B and 3C the effects caused by the projectile pursuant  
10 to Fig. 1 in the zone of the exit crater in the target plate 3. The section 3A  
11 corresponds to the section 1C of Fig. 1. At the time or position 3B, following the  
12 formation of shear fractures, a blow-out zone 7 begins to form which owing to the  
13 described high lateral effects during the penetration is considerably larger than is the  
14 case with common kinetic energy projectiles. As a result of the simultaneously  
15 occurring relief from the rear side of the plate, the pressure zone 4a of the bulging  
16 medium is relieved. The relieved material 1a exits behind the blow-out zone 7 from  
17 the crater (section 3C), followed by the residual projectile 5c. As a result of the  
18 detaching exit crater zone 7a which exits with increasing acceleration and a further  
19 relief, there is usually also a fragmentation of the bulged penetrator zone (casing  
20 zone) 5b from the residual projectile 5c, so that casing splinters 5d form. Owing to  
21 their higher speed, they slide off from the target area 7a which exits at a still relatively  
22 low speed. In this process they are further deflected radially. This causes an  
23 additional enlargement of the exit angle 8 of the splinters 5d.

24  
25 Fig. 4 describes the process according to Fig. 1 and Fig. 3 in an exemplary manner in  
26 a two-plate target.

27  
28 Once a crater was formed in the first plate 3 (section 4a), whose size arises  
29 substantially from the projectile parameters (structure, materials, dimensions, impact  
30 speed) and the target plate data (material, thickness, mechanical properties), the

1 residual projectile 9 which remains after the formation of the casing splinters 5d, the  
2 extracted crater zone 7a and the splinters 5d of the bulged partial zone of the casing  
3 impinge upon the second plate 3a. Section 4B shows a view onto the impacted  
4 second plate 3a. Different crater zones arise: The impact zone 10 which is formed by  
5 the residual projectile 9 and the central part of the exit zone 7a, crater 10a which is  
6 caused by the outer part of the exit zone 7a, and the zone of the splinters 11 which is  
7 produced by the casing splinters 5d. Further outside is the zone 11a of the  
8 splinters 7b extracted from the target material 3.

9  
10 Usually, the outer crater zones in particular will overlap more or less strongly  
11 depending on the physical and technical conditions.

12  
13 When adding further target plates the above descriptions apply analogously. Fig. 5  
14 shows the case where a projectile with a central penetrator 6 according to Fig. 2  
15 penetrates a two-plate target according to Fig. 4. On penetrating the first plate 3 the  
16 descriptions as made in connection with image 4A apply, extended by the central  
17 penetrator 6 or the penetrating penetrator head 6a. Thereafter the residual penetrator  
18 6b penetrates the extracted crater zone 7a and forms a further breakthrough 7c. The  
19 thickness of the second plate 3a was chosen in such a way that it is still penetrated by  
20 the central residual penetrator 6b. Only the respectively shortened residual penetrator  
21 6c exits after the second plate, encompassed by a splinter cone made of penetrator  
22 parts 13 and target splinters 13a which have formed from the breakthrough 7c or  
23 were extracted from the second target plate 3a. This target zone thus corresponds to  
24 the usual penetration image of a kinetic energy projectile with a bulging medium.

25  
26 A section through the second plate 3a shows the different crater zones. At first the  
27 inner crater zone 12, formed by the residual penetrator 6b and the breakthrough 7c,  
28 followed by the zone 10 which is formed by the residual projectile without a central  
29 penetrator 9a. A crater zone 10a follows which is produced by the extracted crater  
30 zone 7a. This is followed by a crater zone 11 produced by the splinters 5d of the

1 fragmented partial zone of the casing. Further outside there is located a crater zone  
2 11a which is formed by the extracted target splinters 7b of the first plate 3.

3  
4 These considerations lead to the conclusion that in the projectile design as described  
5 herein an introduced central penetrator 6 is virtually not impaired in its terminal  
6 ballistic power. Accordingly, its penetration depth corresponds to the performance as  
7 achieved by such massive penetrators alone. This applies analogously with respective  
8 dimensionings also for penetrators which are introduced at other positions in the  
9 bulging medium (preferably in the vicinity of the axes). At the same time this finding  
10 explains how in the case of armour-piercing ammunition a respectively high basic  
11 penetration power is to be combined with the large lateral effects as described herein.

12  
13 As was already mentioned above, experiments with model projectiles according to  
14 Fig. 6 were performed according to the considerations as explained above. The  
15 projectiles consisted pursuant to Fig. 1 of a casing made from tungsten heavy metal  
16 (tungsten heavy metal; length 40 mm, outer diameter 6 mm, inner diameter 3.5 mm,  
17 density 17.6 g/cm<sup>3</sup>) which enclosed the introduced bulging medium of the same  
18 length (diameter 3.5 mm). The rear was formed by a base plate for aerodynamic  
19 stabilization.

20  
21 Fig. 7 to Fig. 11 and Fig. 16 to Fig. 17 show X-ray flash photographs of the  
22 experiments. All illustrations concern two X-ray flash photographs each at two different  
23 times. The left representation shows the impacting projectile (in all graphics and  
24 illustrations the projectile flies from the left to the right side), the right one shows the  
25 respective deformation condition at the time of the photograph. Both relatively thick  
26 one-plate targets (Fig. 7) as well as two-plate targets (Fig. 8 to Fig. 11 and Fig. 16 to  
27 Fig. 17) were shot at.

28  
29 Fig. 7 shows the X-ray flash photograph of an experiment with a homogeneous target  
30 plate 3 made from armour steel (strength approx. 1000 N/mm<sup>2</sup>) of a thickness of

1 25 mm. The bulging medium 1 consisted of a glass fibre reinforced plastic material  
2 with a density of  $1.85 \text{ g/cm}^3$ . The crater contours are entered as broken lines, as is  
3 the crater in dotted lines which is caused by respective comparison experiments of  
4 massive heavy metal penetrators of the same outer diameter. The crater diameters of  
5 the casing 2 consisting of tungsten heavy metal without a bulging medium 1 are  
6 comparable to this.

7  
8 The right section shows a previously unknown, enormous enlargement of the  
9 produced crater, and thus also an enlargement of the exiting splinter cone, formed by  
10 projectile and target splinters.

11  
12 This allowed providing experimental evidence that in the case of massive target  
13 plates there is a perfect function of the bulging medium within the terms as described  
14 herein (according to Fig. 1). The lateral effect was a multiple of all previously known  
15 results. In these experiments, for example, a crater volume of approximately 5 times  
16 more was achieved as compared with the firing with a massive penetrator made from  
17 tungsten heavy metal of the same outside diameter or a tungsten heavy metal casing  
18 of the same mass without a bulging medium.

19  
20 Respective results were also achieved with other bulging media such as copper,  
21 aluminium and polyethylene in the speed range between  $1000 \text{ m/s}$  and  $1800 \text{ m/s}$ .

22  
23 The experiments in connection with Fig. 8 to Fig. 11 were made to provide evidence  
24 that both a relatively weak first plate 3 with simultaneous low density and thus low  
25 specific surface mass causes the full lateral effect and that in this case different  
26 materials other than the bulging material 1 can be used according to the above  
27 statements.

28  
29 A two-plate arrangement according to Fig. 4 was used as a target, with a first plate 3  
30 made from duraluminium of a strength of  $400 \text{ N/mm}^2$  and a thickness of  $12 \text{ mm}$  and a

1 second plate 3a made from armour steel and erected at a distance of 80 mm. The  
2 impact speed in these experiments was between 1400 and 1800 m/s. The projectile  
3 structure corresponded to the structure according to Fig. 6. The bulging medium 1  
4 was varied, with the density being assumed as main parameter according to the high  
5 impact speeds.

6  
7 Fig. 8 shows at first the comparison experiment with a hollow penetrator (i.e. without a  
8 bulging medium) made from tungsten heavy metal with the same outer diameter. As a  
9 result of the relatively light target plate, virtually no plastic head has formed. With the  
10 exception of a small extract on the right side of the X-ray flash photograph, one  
11 cannot recognize any lateral deformation.

12  
13 The glass fibre reinforced plastic material that was already used in the experiment  
14 pursuant to Fig. 7 is used as bulging medium in the experiment in connection with  
15 Fig. 9. The lateral fragmentation occurs to the full extent.

16  
17 Fig. 10 shows an experiment with aluminium as a bulging medium. The lateral  
18 fragmentation occurs according to the explanations made above, but surprisingly  
19 more markedly.

20  
21 In Fig. 11 polyethylene (PE) was used as bulging medium. In this material with a very  
22 low density, but with a sufficiently low dynamic compressibility and relatively large  
23 shock hardness, there is a very marked lateral fragmentation.

24  
25 These X-ray flash photographs confirm that even in the case of perfect lateral  
26 acceleration there are considerable differences in the behaviour of the various bulging  
27 media.

28  
29 Accordingly, in the case of PE as bulging medium with a particularly low density  
30 (Fig. 11) the entire heavy metal casing is slit open over the entire length of the

1 projectile through the first plate for example, with the lateral acceleration of the formed  
2 segments (subpenetrators) occurring continuously from the tip to the rear (cf. Fig. 11,  
3 right side). In the case of aluminium as a bulging medium (Fig. 10) there is an even  
4 stronger lateral effect under the prerequisites which apply to this experiment.  
5 However, only half of the projectile length is strongly bulged.

6  
7 This influence will presumably show even more in using copper or lead as bulging  
8 medium. Owing to their relatively high density they should lead to respectively lower  
9 lateral accelerations at even shorter bulged projectile lengths.

10  
11 In addition to the aforementioned projectile and target parameters, the speed with  
12 which the plastic deformation progresses in a material, but which should not be  
13 confused with the speed of sound which usually expands with a speed of several  
14 km/s, plays an important role in the axial progression of the fragmentation. This speed  
15 range extends from a few 100 m/s up to the magnitude of 1 km/s and thus lies  
16 considerably below the speed of sound of the respective materials.

17  
18 The processes in undammed cylindrical bodies during the dynamic bulging are  
19 discussed in detail and described analytically in the aforementioned doctoral thesis by  
20 G. Weihrauch on page 25 ff on the basis of copper as an example. The contexts  
21 outlined there only apply for freely bulging bodies, i.e. without lateral damming. They  
22 can therefore only be used for principal considerations in connection with the  
23 arrangements as proposed herein. In particular, the lateral damming of the bulging  
24 medium by the ambient material has a decisive influence both with respect to the  
25 lateral as well as the axial deformation speed of the bulging medium.

26  
27 Accordingly, any lateral damming can thus help to achieve, which is also confirmed by  
28 the present experimental results, that even at relatively low projectile speeds in the  
29 magnitude of 1000 m/s the plastic deformation in the bulging medium progresses in  
30 aluminium, glass fibre reinforced plastic material and in particular polyethylene and

1 nylon with relatively high axial speed, which means that it no longer primarily remains  
2 limited to the forward projectile zone (cf. Fig. 11 and Fig. 17 in particular).

3  
4 A comparison of the exemplary chosen materials for the formation of a bulging zone  
5 even in lighter target structures makes clear that there is a plurality of materials which  
6 meet the aforementioned requirements not only in respect of the aforementioned  
7 considerations, but that the properties of the bulging medium can be changed within  
8 wide margins. Moreover, the comparably few examined materials that have been  
9 examined to date show that the lateral effects are adjustable and controllable by way  
10 of the behaviour of the bulging medium under dynamic compression.

11  
12 The experiments also prove that not the special property of pure glass under dynamic  
13 load, but the considerations on which this invention is based are relevant for the  
14 formation of a bulging zone.

15  
16 Ductile materials with higher density (such as soft iron, armco iron, lead, copper,  
17 tantalum, or even also heavy metal additions) open up the possibility to use such  
18 bulging mediums in cases when higher mean densities of the projectiles are required  
19 or when certain constructional demands such as extraballistical demands with respect  
20 to the center-of-mass position have to be fulfilled.

21  
22 Fig. 12 to Fig. 15 show the respective splinter distributions of the experiments  
23 pursuant to Fig. 8 to Fig. 11 on the second target plate 3a. The small craters in the  
24 outermost zone 11a (Fig. 5) which were formed by the extracted target plate  
25 splinters 7b were not taken into consideration.

26  
27 Fig. 12 shows the crater of the reference experiment (Fig. 8) with a hollow penetrator.  
28 It shows the effect of the introduced bulging medium in a comparison with the Fig. 13  
29 to Fig. 15. The crater diameter is approx. 11 mm, and thus lies in the magnitude of  
30 two projectile diameters.



1 Fig. 13, as a splinter image of the experiment (Fig. 9) with glass fibre reinforced  
2 plastic material as bulging medium 1, shows analogously to the description pursuant  
3 to Fig. 4 on the second plate 3a, which is located 80 mm away, a relatively even outer  
4 distribution 11 of the splinters 5d (diameter approx. 90 mm corresponding to 15  
5 projectile diameters) formed from the casing 2, in addition to a considerably enlarged  
6 central crater zone 10,10a in the magnitude of four projectile diameters.

7  
8 Fig. 14 shows the highly interesting crater image to be expected according to Fig. 10,  
9 with aluminium as bulging medium. The large central crater (diameter of approx. 5  
10 projectile diameters) is enclosed by a circle of longitudinal subcraters (diameter of  
11 approx. 10 projectile diameters). The other splinters are distributed in a ring of  
12 approx. 13 projectile diameters.

13  
14 In Fig. 15 (corresponding to Fig. 11), with PE as bulging medium, the formed  
15 subprojectiles produced a relatively large inner crater diameter (approx. six projectile  
16 diameters) which is enclosed by a mixed splinter ring with a diameter of approx. 13  
17 projectile diameters.

18  
19 Principally, the penetration depth decreases in line with the lateral expansion of the  
20 splinters. Here too the known laws of terminal ballistics naturally also apply, so that  
21 the totally formed crater volume corresponds in a first approximation to the projectile  
22 energy introduced in the target.

23  
24 In order to prove the high lateral effects with arrangements pursuant to this invention,  
25 two further experimental studies as proposed and performed by the ISL are  
26 mentioned below. It was intended to test first whether in the case of a considerably  
27 thinner first plate (6 mm as compared with the previous 12 mm of duraluminium) the  
28 lateral effect would still occur with the same projectile dimensions according to Fig. 6  
29 (bulging medium: glass fibre reinforced plastic material). This is confirmed by the X-  
30 ray flash photographs in Fig. 16. According to the prerequisites as chosen herein, the

1 projectile still opens very favourably during the passage through the first plate, but  
2 only over a comparably (Fig. 9) small projectile length. Notice should be taken,  
3 however, that a further fragmentation could be influenced over wide limits both by way  
4 of the bulging medium as well as by way of the geometries.

5  
6 As the dynamic properties of the bulging material which is enclosed by a terminal-  
7 ballistically effective body such as tungsten heavy metal (WS), tungsten hard metal  
8 (WC), or depleted uranium (DU) or high-strength steel, can be evidently be changed  
9 over wide limits owing to the above statements on the density and mechanical  
10 properties, the possibilities concerning the technical arrangement allow the highest  
11 range of possible applications both with respect to construction as well as material  
12 which differ considerably in their width and performance from those when using  
13 materials such as glass or ceramics.

14  
15 As was already mentioned above, the combat against fixed-wing aircraft and  
16 helicopters forms an important field of application for the projectile arrangements as  
17 described herein. A purposeful and, optionally, load-dependent fragmentation of an  
18 ammunition can also prove to be very advantageous for the design of different war-  
19 heads or special-purpose ammunition, right up to combatting tactical ballistic missiles.  
20 Respective arrangements can be used both for types of ammunition with large effects  
21 in the interior of light targets right up to heavily armoured vehicles as well as ships  
22 (Exocet principle). The target scenario to be combatted determines the bulging  
23 medium to be introduced and the dimensionings.

24  
25 The arrangements as proposed herein are principally highly effective in the fields of  
26 application as mentioned so far. In order to secure a high lateral effect, however, it is  
27 necessary to have a pressure and bulging zone. For this purpose it is necessary that  
28 certain physical prerequisites are fulfilled in the bulging medium. Among other things,  
29 the impact shock or load must be sufficiently strong or high on impact so as to initiate  
30 the process. Moreover, the dimensions of the bulging medium and of the penetration

1 material enclosing the same must be tuned to one another.

2  
3 Within the widest of margins these prerequisites are fulfilled at the relatively high  
4 impact speeds as are required in armour-piercing (both rotation-stabilized as well as  
5 aerodynamically stabilized) projectiles or in antiaircraft projectiles for reasons of  
6 external or terminal ballistics alone. The speed range is here approximately between  
7 800 m/s and 2000 m/s. The type and dimensioning of the bulging medium and the  
8 ambient casing or the structure of the subpenetrators primarily determine the desired  
9 effects.

10  
11 At even higher speeds the formation of bulging zones will certainly be even more  
12 marked, which means that the share of the bulging medium can become smaller with  
13 increasing impact speed.

14  
15 In a further experiment it was intended to prove the efficiency of arrangements  
16 pursuant to Fig. 1 at considerably lower impact speeds. A target arrangement  
17 pursuant to Fig. 4 in conjunction with a projectile according to Fig. 6 was used as  
18 reference. Glass fibre reinforced plastic material pursuant to Fig. 9 was used as  
19 bulging material.

20  
21 In the experiment pursuant to Fig. 17 the impact speed  $v$  in the target was only  
22 962 m/s. The right X-ray flash photograph shows that here obviously the speed range  
23 was reached from which the lateral fragmentation is virtually just ensured with the  
24 predetermined geometrical dimensions and the materials used.

25  
26 Owing to the tip pressure occurring during the impact a full lateral fragmentation was  
27 still achieved in the forward part of the projectile. The tip pressure  $\rho_p \cdot C_p \cdot v$  (with  
28  $C_p$  = sound of speed in the projectile material (or in the bulging material, respectively),  
29  $v$  = impact speed and  $\rho_p$  = density of the projectile material (or of the bulging material,  
30 respectively)) is degraded relatively rapidly in the course of the penetration to the

1 quasi-stationary dynamic pressure (Bernoulli pressure;  $\rho_p/2 * u^2$  with  $u$  = penetration  
2 speed). This pressure is determinative for the formation of the following pressure and  
3 bulging zone. The pressure and bulging zone extends here over the entire remaining  
4 projectile length as a result of the lateral damming (compare the statements in  
5 connection with Fig. 11). The casing is thus fragmented in this way into several  
6 longitudinal splinters.

7  
8 Fig. 17A shows the respective crater image on the second plate (distance 80 mm).  
9 The produced central crater corresponds to approx. 5 projectile diameters. The  
10 splinter cone is still very considerable with a circle of approx. 11 projectile diameters.  
11 Evidence was thus provided that the high lateral effects are still ensured at impact  
12 speeds below 1000 m/s. Moreover, the considerations made in conjunction with the  
13 confirming experiments prove that the desired lateral effects can be secured and  
14 varied over wide margins by way of the geometrical arrangement and the choice of  
15 the respective materials.

16  
17 According to the considerations made so far and the findings already made up this  
18 point, it may be assumed that by choosing respective parameters it is possible to  
19 achieve a high lateral fragmentation even at much lower impact speeds. In projectiles  
20 or war-heads with relatively low impact speeds such as merely a few 100 m/s the  
21 margin is certainly limited and the dimensionings and materials must be tuned  
22 carefully with respect to one another. The fragmentation will be supported by thin-  
23 walled casings, for example.

24  
25 In the case of light armourings, for example, jackets which are advantageously thin-  
26 walled and have a terminal ballistic effect and particularly suitable bulging media such  
27 as PE, glass fibre reinforced plastic material or light metals such as aluminium will be  
28 used.

29  
30 It is also possible to strongly reduce the penetration depth by means of respective

1 dimensionings and pairings of materials such as by very thin casings in conjunction  
2 with "sensitive" bulging media and thus to design projectile with no effect or a very low  
3 effect. The use of biodegradable fibre reinforced materials as bulging medium is a  
4 particularly viable possibility. With this novel kind of very light composite materials,  
5 which were mostly developed by DLR Braunschweig, strength values can be  
6 achieved which nearly correspond to those of glass fibre reinforced plastic materials.

7  
8 Such a special case of a cylindrical body with very low penetration power has already  
9 been described in the aforementioned thesis of G. Weihrauch on page 100. From the  
10 equation  $\frac{1}{2} \cdot \rho_p \cdot (v - u)^2 = \frac{1}{2} \cdot \rho_z \cdot u^2 + F$  for  $u = 0$  the values  $F_x = \frac{1}{2} \cdot \rho_p \cdot v_x^2$  are  
11 derived at which no plastic penetration occurs any more. By a respective setting of  
12 the densities and strengths of the bulging medium and of the penetration tool which  
13 encompasses the same it is thus possible to prevent a penetration into the target  
14 structure nearly entirely.

15  
16 A technically highly interesting application is given for this border case also when a  
17 fragmentation of the casing by way of a suitable bulging medium is to occur in such a  
18 way that in the case of special-purpose ammunition, for example, a target is to be  
19 damaged as little as possible and the projectile slides off from a target without  
20 causing any destructions there. For this purpose, however, the target plate must be  
21 sufficiently thickly dimensioned in order to avoid any piercing through. This is  
22 presumably ensured with thicknesses in the magnitude of 0.5 to 1 projectile  
23 diameters.

24  
25 The range of materials as shown herein allows a very wide range of applications,  
26 particularly by also utilizing possibilities for the transmission of forces in the axial and  
27 radial direction in conjunction with a controllable fragmentation mechanism on the  
28 selection or the setting of the material for the bulging zone per se (e.g. by using  
29 plastics, light metals, fibre reinforced materials or other mixtures).

1 Materials such as glass fibre reinforced plastic material or other plastics play a special  
2 role from a technical point of view. As this type of material is only to be used in an  
3 exemplary manner to describe the technical advantages in the realization of the  
4 present invention, the possibilities for the arrangement of the glass fibre reinforced  
5 plastic materials by different production methods shall not be discussed in detail  
6 herein.

7  
8 Only the following shall be stated as catchwords: "share of glass can be altered, types  
9 of resin, filler materials, load-oriented composites, production methods, cross linkage  
10 techniques, gluing techniques, mixing assortments, variable densities, etc.".

11  
12 The temperature behaviour of glass fibre reinforced plastic material is also very  
13 favourable within the terms of the requirements. Moreover, it is known from various  
14 fields of technology that a composite of metallic materials (plates, pipes) with glass  
15 fibre reinforced components (technical glass fibre reinforced plastic material  
16 structures) leads to an overall improved stability under load, particularly in complex  
17 load situation. These occur frequently in applications in the area of ballistics.

18  
19 According to the considerations made above in connection with the example of glass  
20 fibre reinforced plastic material or plastics, or even metallic components, there are  
21 considerable advantages in the application of such materials as dynamic bulging  
22 media in projectiles or war-heads. In addition to extremely favourable mechanical  
23 values, the particularly advantageous technical arrangements and connections shall  
24 be explained below in closer detail.

25  
26 Apart from the circumstance that a very extensive range of materials is available as  
27 effective bodies, the possibility also arises to use prefabricated inserts, for example.  
28 Potential materials are metals with favourable plastic deformation properties such as  
29 lead or copper, materials which can be favourably worked such as light metals,  
30 materials of low density such as plastics (PE, nylon, etc.) and, naturally, primarily

1 materials which are introduced or glued in in a mechanically favourable manner.  
2 Moreover, the bulging medium can be introduced into respective hollow chambers if  
3 provided with liquid, plastic or kneadable properties. In this respect mixtures or  
4 mechanical mixtures are of particular interest.

5  
6 Principally, two directions are imaginable for the introduction into and connection of  
7 metallic materials, plastics or special-purpose materials, and in particular glass fibre  
8 reinforced plastic materials, in structural bodies which are adjacent to or dam up  
9 during the impact or penetration of kinetic energy projectiles and projectile parts:

10  
11 A. The introduction as prefabricated technical structure.

12  
13 B. The introduction as a loose (mush-like or dry) mechanical mixture.

14  
15 Concerning A:

16  
17 1. Metallic materials. Other materials with similar densities and sufficient mechanical  
18 strength and low compressibility. Design of a technical structure.

19  
20 2. The mentioned materials are introduced as prefabricated bodies and are glued or  
21 injection-moulded all around.

22  
23 3. Combinations of 1. and 2.

24  
25 Concerning B:

26  
27 Injection moulding of thermoplastic and fibre-reinforced materials; castable and  
28 pressable mixtures of different materials such as elastomeric materials.

29  
30 DP-RTM methods (duroplastics) for dry inserted mixtures and mechanical

1 mixtures.

2

3 The processes according to B can naturally also be combined with the  
4 technical structures according to A.

5

6 Concerning the technical arrangement and the possibilities for the introduction  
7 of dynamically acting bulging media in projectiles and war-heads, particularly  
8 interesting variants are possible with respect to the effect such as by:

9

- 10 • different materials as bulging media with different specific properties;
- 11 • in the case of glass fibre reinforced plastic materials: different glass contents and  
12 resin types;
- 13 • different radial and/or axial arrangements of the technical structures;
- 14 • mixtures of differently acting materials (such as differences in density and  
15 strength);
- 16 • joining by sliding of prefabricated components (hollow cylinders; telescope; cone);
- 17 • placing partly differently dimensioned bodies next to one another;
- 18 • introduction of special materials with specific effects (e.g. incendiary);
- 19 • introduction of explosive materials;
- 20 • introduction of materials with different terminal ballistic effects;

21

22 The advantages in respect of the production technique for the design of projectiles  
23 and warheads with such dynamically acting components would be, among other  
24 things:

25

- 26 • The inner and outer bodies (penetrator, jacket, casing, inserts) can be provided  
27 with any desired surface. The special-purpose materials bridge the surface  
28 roughnesses for example (cheaper production; possibility of using components  
29 from other production);



- 1 • introduction of duroplastic or thermoplastic resins or elastomers by injection,  
2 pressure or suction;
- 3 • bridging of edges, shoulders and threads or the like;
- 4 • form-locking by way of threads;
- 5 • favourable temperature behaviour;
- 6 • shock resistance (during launching or in special target structures such as bulkhead  
7 arrangements, composite armourings, etc.);
- 8 • controllable fragmentation efficiency;
- 9 • embedding of metallic and nonmetallic bodies such as splinters, rods, cylinders,  
10 balls right up to prefabricated subprojectiles and small bodies of different shapes  
11 and materials.

12  
13 The aforementioned listing shall in no way be regarded as complete.

14  
15 In addition to the above statements, reference shall hereby be made to other  
16 materials than bulging media whose application can be of additional benefit within the  
17 scope of the development of new types of ammunition with high lateral effect. This  
18 relates in particular to the field of the elastomers. Rubber acts, like polyethylene, in a  
19 dynamically incompressible manner when enclosed and can produce very high forces  
20 on the walls surrounding it (hydraulic module). In the case of certain types of rubber  
21 the elasticity module changes discretely by several powers of ten under high dynamic  
22 load.

23  
24 The injection method is particularly employed when using elastomers, which method  
25 creates a plane and highly durable connection to the ambient projectile bodies. Even  
26 complex types of arrangements and connections can be realized in this way in a very  
27 simple manner.

28  
29 It is also possible to fill bulging media with metal powders of high density (tungsten,  
30 etc.) in order to considerably increase the mean density (e.g. glass fibre reinforced

1 plastic material with  $> 3 \text{ g/cm}^3$ .

2

3 The use of powdery materials (metal or other powders) is also of interest as bulging  
4 media, which are introduced either as unsintered pressed powder parts in the  
5 projectile or are pressed directly into the casings in order to increase the density in  
6 the projectile or keep the penetration power low.

7

8 Members of the family of synthetic-resin-compressed wood can also be used as  
9 bulging medium. They comprise a low density and are simultaneously incompressible  
10 and react dynamically in a respective manner (such as Lignostone® with a density  
11 range of  $0.75 \text{ g/cm}^3$  to  $1.35 \text{ g/cm}^3$ ).

12

13 Additional pyrophorous effects in the target after the penetration of the outer skin can  
14 be achieved by adding respective materials (cerium or cerium mixed metals,  
15 zirconium, etc.) which can be incorporated easily in the glass fibre reinforced plastic  
16 materials or elastomer materials. The concentrated introduction or embedding of such  
17 materials is also principally possible.

18

19 The introduction of explosive materials, either as admixtures to the plastic materials or  
20 as explosive per se, can optionally lead to a controllable detonating fragmentation of  
21 the projectile body via the function as bulging medium.

22

23 The aforementioned extremely wide spectrum of possibilities for combination opens  
24 up a completely new field of design for projectiles and war-heads in conjunction with  
25 the technical applications, production aspects and special terminal-ballistically  
26 effective bodies. This wide field of innovations will lead to very interesting concepts for  
27 the widest range of types of ammunition.

28

29 The following figures are used for explaining the possibilities as discussed briefly  
30 above. In this respect, Figs. 18 to Fig. 21 relate more to the technical advantages of

1 the introduction of a bulging medium, whereas Fig. 22 to Fig. 30A relate more to the  
2 technical implementation of such projectiles.

3  
4 Accordingly, Fig. 18 shows the case where a prefabricated body is introduced as a  
5 bulging medium 1 by means of a thread 15, 15a between the ambient terminal-  
6 ballistically effective material 2 and a central penetrator 6. For the purpose of a  
7 stronger connection it is possible to additionally introduce a connecting layer as an  
8 adhesive or soldering layer.

9  
10 Fig. 19 shows a prefabricated body introduced as bulging medium 1 between the  
11 ambient terminal-ballistically effective material 2 and the central penetrator 6. A  
12 connecting medium 16 is introduced in the gaps between the casing 2 and the central  
13 penetrator 6, which medium is preferably used for the transmission of forces.

14  
15 Fig. 20 shows the case that both the inner surface 17 of the projectile casing 2 as well  
16 as the surface 18 of the central penetrator 6 has a random surface roughness or a  
17 surface arrangement. A bulging medium 1 that is injected for example will bridge any  
18 such unevenness and ensures in addition to a lateral effect also a perfect  
19 transmission of forces between the casing 2 and the central penetrator 6.

20  
21 In Fig. 21 the bulging medium 1 is introduced as a prefabricated body with uneven  
22 surfaces. Here a layer 19 with the required properties, which is comparable to the  
23 connecting medium 16, ensure the technically perfect connection between the casing  
24 2 and the penetrator 6.

25  
26 Fig. 22, as a reference figure for the Fig. 23 to Fig. 30A, shows a sectional view  
27 through the projectile pursuant to Fig. 2, which projectile is formed from the  
28 components of a bulging medium 1, casing 2 and partly a central penetrator 6.

29  
30 Bridges 20 as subprojectiles have been introduced in Fig. 23 between the central

1 penetrator 6 and the outer projectile element 2. These bridges 20 of random length  
2 remain substantially excluded from the lateral acceleration. The bulging medium is  
3 used here additionally as a carrier for the subprojectiles (bridges) 20. Respectively  
4 thin bridges 20 can be used for the mere fixing of the central penetrator 6.

5  
6 In Fig. 24 either rod-like or successive bodies 21 with terminal ballistic effect are  
7 introduced into the bulging medium. They are radially co-accelerated as a result of  
8 their arrangement on the outside. In this way prefabricated subpenetrators or other  
9 effective parts can be laterally accelerated simultaneously with the enclosing body.  
10 Fig. 24A corresponds to Fig. 24 without a central penetrator.

11  
12 Fig. 25 shows the case that notches 22 or embrittlements are provided on the inner  
13 side of the enclosing terminal-ballistically effective body 2. They predetermine a  
14 desired fragmentation of the body 2 or support the same.

15  
16 Fig. 26 shows in an exemplary manner a projectile without a central penetrator, with  
17 notches 23 or other measures benefitting the fragmentation being situated on the  
18 outer side of body 2, in contrast to Fig. 25.

19  
20 In Fig. 27, random bodies 24 which are provided with terminal ballistic or other effect  
21 are embedded into the bulging medium. They are only deflected in a stronger radial  
22 manner in the case of a positioning in the outer zone by the formation of the bulging  
23 zone.

24  
25 Fig. 28 shows the respective case without a central penetrator with a larger number of  
26 similar or different bodies 25.

27  
28 A further case which is particularly interesting for the arrangement of such projectiles  
29 is shown in Fig. 29. Four long penetrators 26 are introduced into the bulging medium  
30 in the axial zone, for example.

1 The above examples are to show that any other central penetrators, penetrator parts  
2 or other effective bodies can be embedded and fixed by way of the bulging medium.  
3 This also applies analogously to the case that the bodies 24 and 25 in Figs.27 and  
4 Fig. 28 represent splinters or penetrators.

5  
6 In Fig. 30, a penetrator 27 with a square cross section is introduced as an example  
7 that the bulging medium allows embedding any desired penetrator shapes and also  
8 penetrator materials (they only have to survive the launching acceleration).

9  
10 In addition to Fig. 30, in Fig. 30A the central penetrator 28, which in this case has a  
11 cylindrical shape, is provided with a hollow chamber 29. In this way the mass of the  
12 penetrator can be reduced, for example. Such a hollow chamber can also be filled  
13 with foam or can be used for receiving materials with special properties (pyrophorous  
14 or explosive).

15  
16 Moreover, the positioning of bodies in the bulging medium opens the possibility to  
17 influence the type and the scope of the lateral fragmentation or acceleration.

18  
19 Fig. 31 to Fig. 34 show a number of examples with the principle as proposed herein  
20 from the large number of possible projectile designs and effective zones of projectiles.

21  
22 Fig. 31 shows the case that the bulging medium is located in a stepped arrangement  
23 30. Such a design, for example, reacts very "sensitively" on hitting a thin structure in  
24 the forward part, whereas the rear projectile parts form different subprojectiles or  
25 splinters owing the geometrical arrangement and also by the use of different bulging  
26 media 1b,1c and 1d.

27  
28 Fig. 32 shows a penetrator 31 for increasing the effect in the interior of the target after  
29 a penetration path corresponding to the forward massive projectile part. For this  
30 purpose the bulging medium 1e is located in the rear part of the projectile. Such a

1 projectile 31 is capable of combining high penetration powers with large craters and  
2 respective lateral effects in the interior of the target or the following structures.

3  
4 Fig. 33 shows as a further example a projectile 32 with three separate dynamic zones  
5 and the bulging medium 1f, 1g and 1h. A projectile 32 which is arranged in such a way  
6 is capable, following a partial fragmentation in the case of the thin outer structures, of  
7 developing an increased lateral effect only after the penetration of a thicker further  
8 plate. It is followed by a massive zone for achieving a further, larger penetration path  
9 and thereafter the zone with the bulging medium 1h for increasing the residual effect  
10 (Fig. 32).

11  
12 Fig. 34 shows the cross section through a projectile 33 which comprises, as an  
13 example, in the radial direction two of the effective combinations presented herein  
14 with a bulging medium 1 or 1i between the casings 2 and 2a or the casing 2a and the  
15 central penetrator 6. Such combinations can naturally also be arranged several times  
16 on the longitudinal axis of a projectile or be combined with the examples as  
17 mentioned above.

18  
19 With the effective principle as described herein it is also possible to equip projectiles  
20 which contain constructionally predetermined, enclosing bodies with terminal ballistic  
21 effect. Fig. 35A to Fig. 35D show four examples which also apply analogously for  
22 projectiles with an additional central penetrator.

23  
24 In Fig. 35A the outer casing 34 which dams up the bulging medium consists of a ring  
25 of longitudinal structures. They are either mechanically solidly connected with one  
26 another, e.g. also by thin sleeves, or glued or soldered together. It is also possible to  
27 treat the casing by a respective treatment such as inductive hardening or laser  
28 embrittling in such a way that the same is fragmented into predetermined bodies  
29 under dynamic load.

1 Fig. 35B shows the case that a casing damming the bulging medium, which  
2 corresponds to casing 2 of Fig. 22, is encompassed by an outer casing 34 according  
3 to Fig. 35A. In Fig. 35C random bodies 37 are embedded in the casing 36. In Fig. 35D  
4 a ring of subpenetrators or splinters 34 is located on the inner side of the outer  
5 casing 35, corresponding to Fig. 35B.

6  
7 A further element which is important for the efficiency of a projectile is the projectile  
8 tip. Below, a number of principal examples are shown (hollow tip, massive tip and  
9 special forms of tips), with the arrangement of the tips principally considering the full  
10 effectiveness of the principle as described herein, which means that it does not  
11 negatively influence the same or supplements it in a positive way.

12  
13 Fig. 36 shows an example for hollow tips 38. They are used primarily as extraballistic  
14 hoods and are immediately destroyed on impacting even light structures, so that the  
15 lateral acceleration process can be initiated immediately by the impact shock, as was  
16 already described. Fig. 37 shows a tip 39 according to Fig. 36, filled with a bulging  
17 medium 40. Fig. 38 shows a massive tip 41. It can be of one or several parts and is  
18 used in cases where more massive preliminary armourings are to be penetrated  
19 without any immediate fragmentation of the projectile.

20  
21 Fig. 39A and Fig. 39B are used as examples for special forms of tips. In Fig. 39A the  
22 bulging medium 42 reaches into the tip 43. In Fig. 39B the tip 44 comprises a bulging  
23 medium 45 in partial zones. By way of the arrangement, design or selection of  
24 material of the respective tip or the forward part it is possible to start the initiation of a  
25 high lateral effect both in an accelerated manner (by a particular rapid transmission of  
26 the shock load and thus rapid buildup of pressure) as well as in a delayed manner.  
27 This is of interest, for example, when the lateral splintering effect is to occur at a  
28 specific target depth or in a specific target region.

29  
30 It is also possible by means of a forward or lateral (outer) "protective apparatus" to

1 bring superstructures with the described lateral effect to the desired location in a  
2 target structure, so that this effect will truly become effective only at such a location.  
3 Such a protective casing can also form a hollow chamber between the outer casing  
4 and the arrangement for the achievement of the lateral effect. Similarly, the protection  
5 can be formed by a buffering material which forms the outer casing either by itself or  
6 is introduced in the aforementioned hollow chamber. Such a protective casing can be  
7 of particular interest in war-heads, because with their help it is possible to introduce  
8 individual or a plurality of apparatuses for achieving a high lateral effect into the  
9 interior of a hardened or unhardened war-head and will thus allow the effect to spread  
10 only there.

11  
12 By the equipment of a war-head with the devices as described herein it may also be  
13 desirable to achieve different lateral effects and/or depth effects by mixing different  
14 bodies. This can occur in such a way for example, that respective cylinders with  
15 different geometries or wall thicknesses or casing materials are provided with different  
16 bulging material fillings.

17  
18 A further technically very interesting application of the lateral concept as outlined  
19 herein may be obtained when ammunition bodies or war-heads are to be converted or  
20 disposed of. It may be of economic interest to change from a too expensive or too  
21 ineffectual concept to a novel technology. Thus it is imaginable that parts of the  
22 ammunition are removed and replaced by bodies with the high lateral effect as  
23 described herein. It is also possible to press in a plastically deformable body or to  
24 introduce the same by way of casting into a predetermined projectile (with or without  
25 inner parts) in such a way that the lateral effect as described herein can occur in the  
26 now modified projectile.

27  
28 It is also imaginable to replace pyrotechnical apparatuses in projectiles or war-heads  
29 by inert materials (bulging materials) or, to the extent as is permitted by the safety  
30 regulations, to embed the same partly or entirely in these in order to obtain inert



1 effective bodies with high lateral effects. Such reconfigured ammunition bodies or  
2 war-heads can then be used according to the altered effect for new purposes or be  
3 used as exercising ammunition.

4  
5 The lateral principle as described herein can be used:

- 6  
7 • for fighting missiles and war-heads (TBM);  
8 • as effective or partial component in war-heads and missiles.

9  
10 In combatting war-heads, and TBM's in particular, one can assume very high impact  
11 speeds. This not only supports the build-up of a pressure field and thus the initiation  
12 of high lateral effects, but the share of the effective bulging medium mass required for  
13 the effect is reduced accordingly. In all other respects the laws apply in combatting  
14 hardened or unhardened war-heads which have already been discussed in the  
15 description of the lateral effect against different targets.

16  
17 If the principle as described herein is used in missiles, ejection bodies  
18 (subammunitions) and war-heads of guided or unguided missiles, either the body can  
19 be arranged according to the concept as proposed herein or it is used as a vessel for  
20 one or several apparatuses for producing high lateral effects.

21  
22 While the invention has been illustrated and described as embodied in a projectile or  
23 war-head, it is not intended to be limited to the details shown since various  
24 modifications and structural changes may be made without departing in any way from  
25 the spirit of the present invention.

26  
27 What is claimed as new and desired to be protected by Letters Patent is set forth in  
28 the appended claims: